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Identifying characteristics of deaf poor readers

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Identifying Characteristics of Deaf Poor Readers

Master's Project

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By

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Section One

Project Summary

The hallmark of learning disability (LD) is a discrepancy between intellectual ability and academic achievement, which results from cognitive processing deficits. Deaf and hearing LD individuals experience difficulties in one or more of the following: (a) one academic area despite adequate or superior performance in other classes, (b) expressive and receptive language – reading, writing and signing, (c) social perception and competence, (d) problem solving (can be rigid thinkers), (e) gross and fine motor coordination, (f) test taking, (g) remembering specific tasks and rules, (h) organization, time management, (i) following directions or instructions, (j) spelling or handwriting, (k) memory, (l) perceptual discrimination, (m) attention and concentration, and (n) distinguishing essential from nonessential (Rush & Baechle, 1992). LD individuals demonstrate poor academic performance *despite* having average or above average intellect. Because the definition of LD excludes sensory deficit and environmental factors as possible causes, assessment in deaf individuals is a complicated matter. Deafness, itself, has a wide variety of potential effects on language acquisition, making deafness a formidable confound in most LD testing. However, spelling processing has recently been identified as a potential marker for deaf individuals with LD (Berent et al., 2000), in a parallel situation to hearing individuals with LD (Moran, 1988, in Berent et al., 2000). This study will investigate whether "good" and "poor" deaf readers differ in their spelling recall performance under three

conditions – fingerspelling, sign and print – and whether poor deaf readers can be reliably differentiated according to the presence or absence of LD.

Section Two

Project Description

This study is a spelling recall task. Stimulus words will be presented in three conditions – fingerspelling, sign and print. All subjects will encounter all three lists, presented serially, with brief pauses in between. Each list will comprise 18 words. In order to control for the familiarity effect, no word will be included in more than one list. Students will be instructed to write down the word they see. Data will be analyzed to determine whether or not "poor" readers evidence a different spelling error "profile" than "good readers." Spelling performance will also be correlated with Digit Span (DS) and Symbol Digit Modalities Test (SDMT) performance in an effort to determine whether any relationships exist.

Need Statement

Learning Disability (LD) is the name given to a group of specific learning disorders, including but not limited to "dyslexia, spatial cognition disorders, social intelligence disorders and auditory language processing disorders" (Samar et al., 1998). LD affects 10-20% of hearing children and adults (Samar, 1999). According to Gallaudet's 1997 annual survey of schools and programs, the incidence of LD in deaf children is between 8.4 and 11% (Samar, 1999).

However, because LD and deafness share many common etiologies (e.g., maternal rubella, Rh incompatibility, meningitis, anoxia, complications of prematurity and cytomegalovirus infection), it would not be surprising if the incidence of LD were shown to be higher amongst deaf than amongst hearing individuals. In fact, according to one study, surveyed teachers of the deaf reported 23% of their students as LDHI, or learning disabled with hearing impairment (Roth, 1991). Huge discrepancies exist between individual reports. However, even Gallaudet's conservative 1997 estimate of between 8.4 and 11% "makes LD the largest secondary disability affecting deaf people" (Samar, 1999; Pollack, 1997).

Accepting that the incidence of LD in deaf populations should at least rival (if not exceed) that in hearing populations ("the prevalence of other disabilities in addition to hearing loss is approximately three times as large in the deaf or hard of hearing population as in the general school population," Pollack, 1997), one might wonder why the numbers aren't equivalent. Though LD has been declared for up to 20% of hearing individuals, estimates for deaf individuals continue to hover just under the 10% mark. There are several explanations for the relative paucity of LD diagnoses amongst deaf children and adults. Some are historical, while others are more practical. Historically, the most frequently cited "culprit" is the exclusionary clause of Public Law 94-142 (1975), which stated that a specific learning disability "does not include children who have learning problems which are primarily the result of visual, hearing, or motor handicaps" (Roth, 1991). Though several revisions have been proposed, most notably by the National

Joint Committee on Learning Disabilities (NJCLD), current federal law still regards deafness and LD as mutually exclusive. In fact, "many states still do not recognize the possibility that deafness and LD may co-occur" (Samar, 1999). This failure to recognize deafness and LD as distinct entities has had the unfortunate consequence of disqualifying many LDHI students from LD support services and remediation to which they are entitled under Section 504 of the Rehabilitation Act of 1973 (Rush and Baechle, 1992).

Though history, including the very separate training of deafness and LD professionals, has had a profound impact on the current landscape, there are other, perhaps more practical reasons why LDHI diagnoses are relatively scarce (only 1% documented increase in incidence from 1984-85 through 1994-95, Schildroth & Hotto, 1996). Deafness can significantly confound LD assessment procedures, as it frequently results in pervasive (English) language disability. "Deafness introduces complex interactions between audiological, cognitive, cultural, and language factors that create enormous variability in English language skills in reading, writing, vocabulary, grammar, meaning, and discourse" (Samar, 1999). In fact, demographic studies suggest that deaf students experience little growth in reading achievement between ages 13 and 20. Furthermore, only about 10% of deaf young adults read at the eighth grade level or higher (Trybus and Karchmer, 1977, cited by Crandall, 1982). It is often difficult to detect genuine LD against this background of thwarted English acquisition. The situation is made particularly acute by the lack of LD assessment measures valid for use with deaf populations. Therefore, development of a standard test battery and adequate test norms is essential.

Significance of the Project

Dyslexia, or Specific Reading Disability (SRD), is present in 80% of hearing individuals with English language learning disability (LLD) (Samar, 1999). The disorder is believed to have a neurobiological etiology. "Dyslexia is often linked to abnormalities in physiological development or functioning of the brain, specifically the left hemisphere" (Lipa, 1983). Dyslexic individuals often confuse small, similar words (e.g., *horse* for *house*, *cold* for *could*, *how* for *now*, *this* for *that*). They may also have difficulty discriminating alphabet letters, learning letter names and discerning part-whole relationships (Lipa, 1983). Dyslexics characteristically commit reversals, whether of individual letters, whole words or numbers. Therefore, "difficulty or dysfunction in temporal order processing is considered a prime cause of reading disability" (Lipa, 1983).

Specific Reading Disability, or developmental dyslexia, is distinguished from Non-Specific Reading Disability (NSRD) in that the former involves deficient word decoding with adequate comprehension, while the latter involves precisely the converse (Aaron, 1995). Because of this, additional symptoms of dyslexia include "poor decoding, slow reading, errors in oral reading, poor spelling, errors of written syntax and excessive reliance on context for word recognition" (Aaron, 1995). Poor spelling is a concomitant of reading disability because spelling-to-sound relational rules are believed to be involved in both reading and spelling

(Aaron, 1995). Furthermore, spelling difficulties are thought to be more indicative of SRD than NSRD, which is generally characterized by the misspelling only of particularly challenging words (Aaron, 1995).

One would expect the prevalence of dyslexia to be at least as high in deaf populations as in hearing. However, because there is currently no satisfactory way of detecting LD and its most common manifestation, dyslexia, in deaf individuals, many deaf dyslexics escape detection. To circumvent the language issue, researchers seek to discover a physiological marker for dyslexia. "A diagnostic marker for dyslexia in deaf individuals must…detect the presence of a neurobiologically based dyslexia but be insensitive to the ordinary developmental influences of deafness on reading skill development" (Samar et al., 2002). Excitingly, the same magnocellular system deficit that has been observed in hearing dyslexics has recently been demonstrated in deaf poor readers (Samar et al., 2002). However, widespread diagnostic neuroimaging hardly seems a plausible alternative to conventional paper-and-pencil testing for LD. In fact, its best use would be as part of a more extensive testing regimen following initial LD suspicion.

So the question becomes: Is there a single characteristic which can be considered a reliable "red flag" for detecting deaf individuals with LD? Consistent with the literature on SRD, spelling has been determined as "the skill that English language professionals perceived as most clearly distinguishing LD deaf students from typical deaf students" (Berent et al., 2000). This finding replicates existing literature on hearing dyslexics, amongst whom "lower levels of spelling accuracy were found to be the only characteristic that distinguished LD students from poorly achieving students without learning disabilities" (Moran, 1988, cited in Berent et al., 2000). Deaf students without LD generally demonstrate good spelling facility. "Unlike deaf individuals' academic achievement in the areas of reading and vocabulary, which has been shown to be severely retarded in comparison to hearing norms, their spelling achievement is relatively advanced" (Bochner, 1982). Superior performance relative to age-matched hearing students is attributed to diminished likelihood of committing auditory confusion errors, which constitute the largest group of spelling errors in the latter group (Bochner, 1982). Because spelling does not pose a special challenge to deaf students in general, it is seems a reasonable "red flag" for detecting those with LD.

Design of the Project

Subjects

Subjects include post-secondary deaf students ages 18-30. In order to elucidate potential differences between "good" and "poor" readers, pilot project participants will be solicited from courses theoretically representing opposite ends of the academic spectrum.

"Good" readers will be solicited the RIT Written Communication II Course. Students enrolled in this course are believed to possess grade 10.0 or higher grade-equivalent reading scores on the California Reading Subtest of the Differential Aptitude Test. Initial contact with Department Chair Linda Rubel yielded the names of the four faculty teaching sections of the course in the spring: Jill Bradbury, Lorna Mittleman, John Panara and Michelle Policano. Of these, only the first two replied to initial solicitation by email on December 16, 2002. Further inquiry has revealed that only the first three faculty mentioned above are actually teaching the course this spring. They will all be contacted a second time during the first week of spring quarter, March 10 – 14, 2003.

"Poor" readers will be solicited from the NTID Reading II Course, which represents California reading scores equivalent to grades 7.0-7.9 (N.B. the NTID Reading I course, which corresponds with reading scores less than grade 7.0, will not be offered this spring). Department Chair Stephen Aldersley has agreed to encourage the relevant faculty to "incentivize" their students' participation. Patty Kenney has already offered her assistance with the project. Kathleen Crandall will be contacted a second time during the first week of spring quarter to see if she might also help.

Data collection will take place during the fourth (and possibly fifth) week of spring quarter. Slots will be made availability between March 31 and April 11, 2003. The PI hopes to circulate a sign-up schedule amongst the students during the first week of spring quarter. She will then finalize testing dates based on student availability. Testing will take place outside class time on a voluntary basis. If participation of students enrolled in the targeted classes is low, the PI will solicit from the NTID student database via email.

Sample sizes for this study are only limited by the availability of willing poor and good readers within the time frame allotted. The PI will collect demographic information on participating students, including age, gender, vision, pure-tone average (PTA) and sign language proficiency as reported in the language-based questionnaire (LBQ). However, this information will use to gain knowledge of, not screen, participants.

Tests

The current study seeks to build on literature singling spelling difficulty out as a potential diagnostic indicator of LD in deaf populations. Its purpose is to investigate possible relationships between spelling performance, reading ability and performance on Digit Span (DS) and Symbol Digit Modality Tests (SDMT). The PI wishes to determine whether spelling – as elicited through fingerspelling, sign and print – can distinguish between deaf individuals with LD and "garden variety" poor deaf readers (i.e., those without a processing disorder).

The pilot study will comprise three individual tests. The first is a spelling test. Stimuli will be presented under three conditions in an attempt to dissociate mode of presentation (fingerspelling, sign or print) from mode of recall (print). The three lists, each of 18 lexical items, will be presented serially. Each stimulus will be presented for 5 seconds. Students will be instructed to wait 10 seconds before writing their responses so that they are forced to keep the stimulus in their working memory. They will then have 10 seconds in which to write their responses before presentation of the next stimulus item. Following a one-minute pause after the final lexical item, students will engage in a free recall task in which they will write down any and all items they remember from all three lists.

The goal of this long-term memory task is to see if more or fewer spelling errors occur when participants are processing words through their own systems (and not merely repeating what they see flashed on a screen).

To differentiate bona fide processing difficulties from the English language problems that sometimes accompany deafness, two auxiliary tests will be administered, both of which circumvent language. The first of these is adapted from Elizabeth Koppitz's Visual Aural Digit Span Test (1977). This test assesses the subject's ability to "process, sequence, and recall visual stimuli by presenting series of digit sequences" presented in order of increasing length, from two to seven digits (Koppitz, 1977, in Parasnis et al., 1996). The subject is shown a sequence of digits for 10 seconds and asked to reproduce the sequence on a blank page. If he reproduces it accurately, he is shown the next longer sequence of digits in the series. If not, he is shown a different sequence of same digit length as the one he has just failed. The test is terminated when the subject fails two consecutive trials for a given digit length.

The second auxiliary test is the Symbol Digit Modalities Test (SDMT, Smith, 1995), which requires the subject to convert a meaningless sequence of geometric symbols to a sequence of digits using a key at the top of the test page. This test has likewise been chosen because it is non-linguistic and can yield valuable information about print processing.

Stimuli

Stimuli include signed, fingerspelled and printed words selected from Vocabulary Norms for Deaf Children (Silverman-Dresner & Guilfoyle, 1972). Only print words recognized by at least 65% of deaf children ages 14 through 15 are included. This list has been narrowed further by selecting only those words which fulfill all of the following criteria: (a) noun, (b) five to nine characters in length, (c) unambiguous English gloss (i.e., excluding ASL signs with one-to-many correspondences with English words), (d) not part of a noun-verb pair (e.g., "plane-fly"), (e) not represented by a compound sign (e.g., "bedroom"), (f) not easily confused due to a change in initialization (e.g., "doctor" and "nurse"), and (g) not represented in ASL by pointing (e.g., "nose").

Words satisfying the above criteria have been randomized to three lists of 20 items using the random number generator featured at www.random.org. List equivalency has been established according to the following criteria: (a) mean character number within lexical items, (b) distribution of word length by list, and (c) mean word recognition frequency, which are reported in figures 1 and 2 below.

RIT interpreter and native signer Cynthia Johnson has recorded the signed and fingerspelled stimuli on film using technical help from the ITV department. The film will be digitized and edited using the Video Wave III SE application for PC.

The printed English stimuli will be typed in a suitable Microsoft Office application.

All stimuli – fingerspelled, signed and printed – will be displayed as a timed Power Point presentation.

The digit span task will be constructed pursuant to instructions from the Visual Aural Digit Span Test (Koppitz, 1977). Modifications may be made to allow group administration.

The Symbol Digit Modalities Test will be administered according to instructions provided by its publisher, Western Psychological Services.

Procedure

Students will be tested in either an individual or group setting, depending on the popularity of the available time slots. Regardless of the setting, students will provide their own answers without help from others. Students will be required to read and sign a consent form, acknowledging their voluntary participation. They will be presented with printed instructions for each of the three tests – spelling, Digit Span and SDMT. The PI will sign the instructions once using Pidgin Signed English (PSE) and will respond as fully as possible to any questions or queries before testing begins.

Management Plan

January – submit proposal rough draft to project mentors for additions and corrections

February – record fingerspelled and signed stimulus words in ITV studio with CJ

March – submit grant proposal to IRB; edit stimulus word video clips; contact Written Communication and Reading course instructors; solicit student participation; determine data collection dates and times

April – collect and analyze data

May – analyze and interpret data; submit finalized grant proposal to masters project committee

Budget

The Department of Educational Research has set up a budget to cover non-cash incentives (e.g., Ben & Jerry's scoop certificates) for participants in the pilot study. There are no additional costs associated with the study at present. All individuals involved with its design and execution are working "pro bono."

Evaluation Plan

The following aspects of the pilot study will be specifically evaluated subsequent to data collection and analysis:

1) Stimulus word selection – were stimulus words too easy or too difficult (i.e., did they elicit errors from too many or too few students)?
2) Stimulus word execution – were stimulus words presented in a clear and comprehensible fashion?
3) Word presentation length – were words presented for a suitable amount of time (i.e., not too long, not too short)?
4) Word presentation speed – was the pause between presentation of consecutive words of suitable duration (i.e., not too long, not too short)?
5) Pause between lists – was the pause between presentation of consecutive lists of suitable duration (i.e., not too long, not to short)?
6) Subject number – was the non-cash incentive sufficient enough to elicit participation in the study?
7) Subject background – did solicitation of RIT and NTID English courses yield suitable numbers of both “good” and “poor” readers?
8) Data analysis – were errors analyzed in a way that yielded meaningful results?

Section Three

Pilot Study (Plan)

Data will be analyzed using appropriate statistical methods. Spelling performance will be analyzed to determine the numbers and kinds of errors that have occurred (e.g., deletions, transpositions), list affiliation (e.g., has any one presentation condition elicited significantly more spelling errors than the others?) and possibly linguistic category (e.g., are errors primarily semantic, morphologic phonologic, or a combination?). Digit Span results will be analyzed with regard to how many digits have been correctly recalled ("loose ordering"), as well as with regard to the accurate ordering of these digits ("strict ordering"). The results of the Digit Span test and SDMT will be analyzed to determine if LD is indicated in poor deaf readers with weak spelling performance.

Pilot Study (Results)

Descriptive Statistics

Thirteen subjects participated in testing. One (VJ), however, was excluded from subsequent data analysis, because he lacked exposure to ASL. (VJ, a native BSL user, had only recently begun to learn ASL and described ASL fingerspelling as a particular weakness.)

Eight males and 4 females were included in the sample. Their mean age was 20.89 years (approximately 20 years, 10 months and 21 days). Their average PTA in the better ear was 102.3 dB (SD = 14.5 dB, range = 75 – 120 dB). Fifty percent of subjects (N = 6) used hearing aids and 8% (N = 1) used a cochlear implant. The remaining 42% of subjects used neither hearing aid, nor cochlear implant.

Sixty-seven percent of subjects (N = 8) described hearing loss at birth. An additional twenty-five percent (N = 3) described hearing loss that occurred between the ages of zero and two. One subject described hearing loss that occurred between the ages of 5 and 12. Subjects were not questioned about the etiology of their hearing loss.

Fifty-eight percent of subjects (N = 7) named ASL as their first language. Thirty-three percent (N = 4) named English. Eight percent (N = 1) named both ASL and English. Seventy-five percent of subjects (N = 9) responded to the item on sign language skill. Their average self-rate was 8.2 (0 = no skill, 9 = extensive skill) (SD = 0.44, range = 8 – 9). Ninety-two percent of subjects (N = 11) responded to the item asking at what age their learned or acquired sign language. The mean for this item was 3 years of age (SD = 1.67 yrs, range = 1 – 6 yrs).

Subjects identified no known learning disabilities or other disabilities. Though 42% (N = 5) of subjects admitted to using corrective lenses (either glasses or contacts), none had a vision problem severe enough to preclude successful participation in the study.

All subjects were currently enrolled in NTID's Reading II course. Twenty-five percent (N = 3) were concurrently enrolled in NTID's Writing II course. Classification to either Reading or Writing II is based on a California Comprehensive Reading Test score less than 7.9. The 12 subjects had a mean California score of 6.8 (SD = 0.7, range = 5.8 – 7.7). They had a mean Michigan Test of English Language Proficiency score of 48.6 (SD = 5.6, range = 38 – 57). No "good" readers participated in testing.

Data

SDMT Scores:

	Mean	SD	Range
Raw	55.167	13.56	26 – 73
Percentage	97.2%	2.4%	93 - 100

SDMT is designed to detect students who are neurologically compromised in one way or another. It usually takes into account both number of items attempted and percentage successfully completed. In our study, the mean percentage successfully completed was 97.2, which is pretty high and does not point to any kind of neurological abnormality. However, though the range of percentages successfully completed only spanned from 93 to 100, the numbers of items attempted varied widely (mean = 55.167, SD = 13.56, range = 26 – 73). For example, subject DH scored 100% correct, but only attempted 26 items in 90 seconds. (As a point of comparison, subject KM attempted 73 items and answered 100% correctly.) If one were to look only at the percentage DH answered correctly, one would not suspect any kind of neurological dysfunction. However, if one realizes that he attempted only one-third of the items others attempted in the same amount of time, his slow rate of processing might point to neurological dysfunction (though not with any certainty, as the SDMT has not been normed on deaf test-takers).

Reading and Language Scores:

Test	Mean	SD	Range
California	6.8	0.7	5.8 – 7.7
Michigan	48.6	5.6	38 - 57

The 12 subjects had a mean California Comprehensive Reading Test score of 6.8 (SD = 0.7, range = 5.8 – 7.7). Thus, the sample did represent the target population of deaf readers with California scores less than 7.9. These were taken to be "poor" deaf readers.

The subjects had a mean Michigan Test of English Language Proficiency score of 48.6 (SD = 5.6, range = 38 – 57). This is a pretty wide range considering that the sample had already been limited to "poor" readers.

Digit Span Scores:

Successive:

	Mean	F(1,11)	P-Value
Strict	5.167	3.143	n.s.
Lax	5.5		

Simultaneous:

	Mean	F(1,11)	P-Value
Strict	6.75		n.s.
Lax	7.083		

There was no statistical difference between strict and lax scoring of the DS tests in either the successive or simultaneous conditions. Therefore, we decided to compare only the strict scorings for the two tests.

Strict Presentation:

	Mean	F(1,11)	P-Value
Successive	5.167	6.026	<0.032
Simultaneous	6.75		

Performance under the simultaneous presentation was statistically better than performance under the successive presentation. This finding is consistent with the previous finding (Parasnis,1998) that deaf college students compared to their hearing controls show shorter digit memory span when the digits are presented successively but not when they are presented simultaneously.

Correlations:

	Correlation	P-Value
S Recall, SDMT (%)	-0.904	<0.0001
Michigan, F total %	0.851	0.0002
P Total %, SDMT (%)	0.735	0.0049
Michigan, S total %	0.712	0.0076
SDMT (%), simultaneous DS (strict)	-0.666	0.0158
S total %, F total %	0.611	0.0329
S Recall, P Total %	-0.602	0.0369
PTA, P Total %	0.601	0.0373
PTA, F total %	0.584	0.0449

Only those nine correlations represented in the table above approached statistical significance (P-Value < 0.05).

Presentation ANOVA:

	Mean	SD	Std Error	F(2,22)	p
P Total	93.5	5.7	1.7	17.082	0.0001
F Total	62.0	24.8	7.2		
S Total	87.5	9.6	2.8		

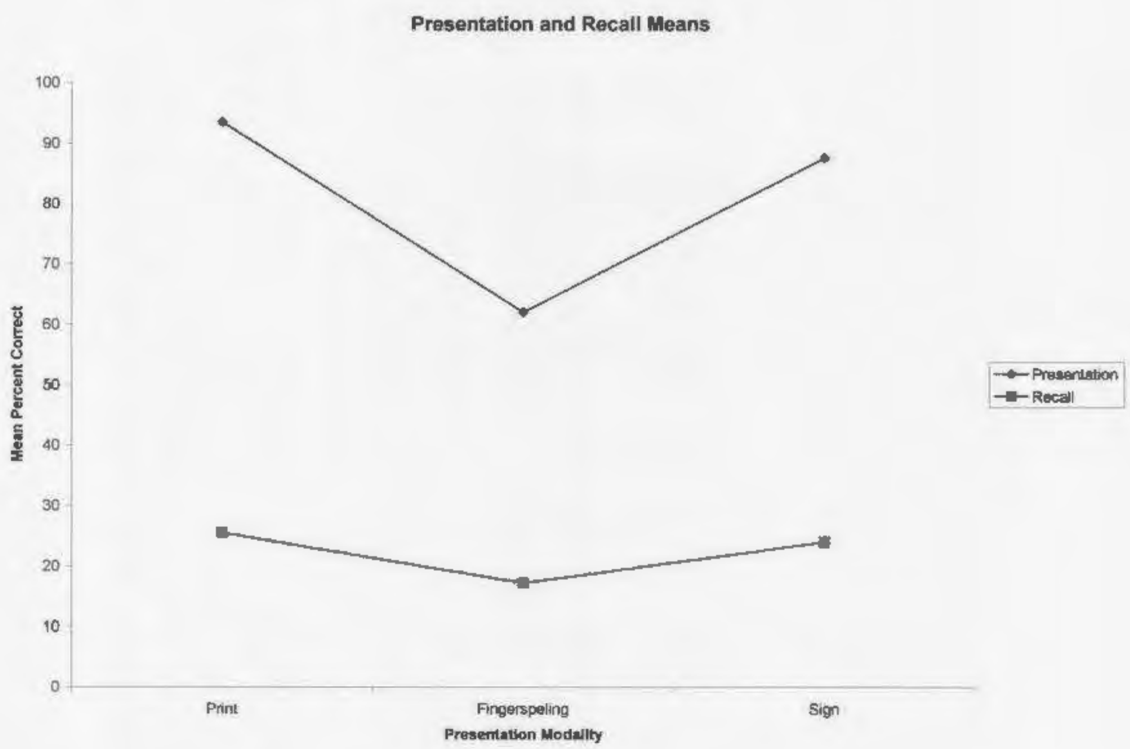
The p-value (0.0001) of the Presentation ANOVA suggests a significant difference between at least two of the three modalities tested – print, fingerspelling and sign. Subsequent pairwise comparison has shown that the fingerspelling total is significantly lower than either the print or sign totals. However, the print and sign totals do not differ significantly from one another.

Recall ANOVA:

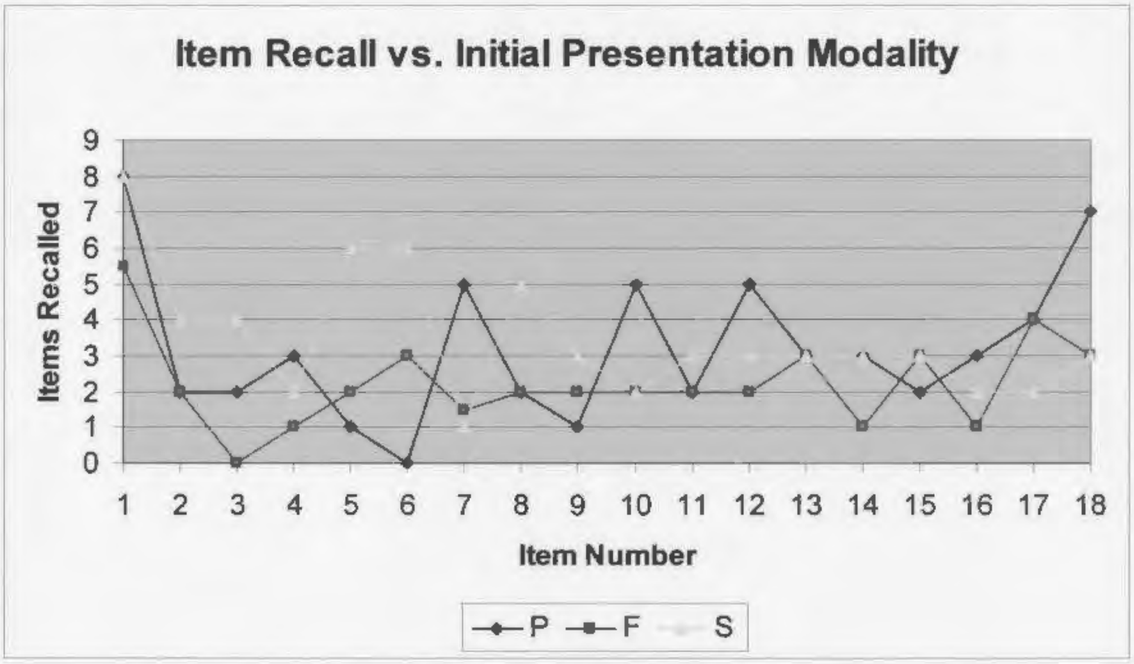
	Mean	SD	Std Error	F(2,22)	p
P Total	25.5	9.9	2.9	1.977	n.s.
F Total	17.2	9.3	2.7		
S Total	24.0	14.1	4.1		

The p-value (0.1596) of the Recall ANOVA does not suggest statistically significance between the recall of words presented in the three different modalities.

Presentation and Recall Means:



Recall Profiles:



Discussion

Study Limitations

The first thing that should be iterated is that this was only a pilot study. As such, it suffered from several limitations, most markedly small subject number. Originally, test subjects were meant to include both "poor" and "good" deaf readers. However, no good deaf readers appeared for testing. This effectively limited the subject pool to an unrepresentative slice of the total population of deaf readers. Therefore, one can only speculate how data obtained from good deaf readers might have appeared. This is one reason why it would be particularly advantageous to repeat this study with a larger N, including balanced numbers of poor and good deaf readers.

Presentation Data

The most visible finding of this study pertains to spelling test performance as a function of modality of presentation. Referring to the "Presentation and Recall Means" graph, one notices an appreciable dip in performance for items presented in fingerspelling. This chevron-pattern of performance was obtained despite having corrected for items in the fingerspelling and spelling lists that may have been unclear or ambiguous. As indicated by the related ANOVA results, subjects performed significantly better on both the printed and spelling lists than on the fingerspelled list. However, there was no significant difference between performance on the print and sign lists.

This last finding is surprising, considering that the signed stimuli did not provide any hints as to how the items were spelled. Subjects viewing signed stimuli had to generate spelling of the items internally. Yet, they seem to have done this no less well than they performed on the printed list. Yet the printed list not only provides the concept behind the word (that is, if a person is assumed to be literate), but also provides information about the spelling of that word through its orthography. Therefore, one would suspect that performance on the printed list would exceed that on the signed list. However, this was not the finding here. Perhaps the "hints" provided by the orthography were "cancelled out" by certain words that subjects were unable to identify. However, as words were specifically chosen with deaf readers in mind, this does not seem a very tenable explanation.

It was not particularly surprising, however, that subjects performed consistently worse on the fingerspelling list than on either other list. Correct spelling of the fingerspelled items required not only one's own inherent spelling ability, but also successful decoding of a rapid, successively presented, highly decontextualized visual stimulus. This is a fairly demanding task. It would be interesting to explore whether "good" deaf readers have more success at it (i.e., whether their data yield a less exaggerated chevron pattern).

Recall Data

The recall data mirror the presentation data pattern. However, the chevron is considerably shallower. ANOVA indicates that the difference in recall means between the three modalities of presentation is not statistically significant. The small number of subjects did not allow a very robust statistical test for significance, so perhaps the numerical pattern will become significant upon repeating the experiment with a larger N.

The recall data were further analyzed to look for evidence of either primacy or recency effects. Though the 13 subjects taking the test had been randomized to three different presentation order groups (FSP, PFS or SPF), elimination of VJ for data analysis reduced the effectiveness of the attempted balancing (5 PFS, 4 FSP, 3 SPF). Nevertheless, analysis proceeded on the assumption that the subjects were relatively well balanced, and item position analysis suggest that while all three presentation modalities manifest fairly robust primacy effects, only print seems to have evidenced any appreciable recency effect (see "Item Recall vs. Initial Presentation Modality" graph above). Of course, this finding should really be substantiated in further studies with larger N values.

Correlation Data

These data suggest that performance on the fingerspelling and sign tests correlates with Michigan score ($F = 0.851$ and 0.712; $P = 0.0002$ and 0.0076, respectively), while performance on the print test does not ($F = -0.108$, $P = 0.7442$). The implication of this finding is that the ability to decode print is not related to overall language facility, which is quite surprising. In contrast, correlations using California scores did not approach statistical significance. Perhaps this is because the population of deaf readers had already been considerably restricted (i.e., to poor readers). Furthermore, multiple regression demonstrates that PTA does not make a statistically significant contribution to subject performance on either the Michigan or California tests. Therefore, it has been eliminated as a potential confound.

Item Analysis

Errors were classified into the following 12 categories:

(1) spelling
(2) spelling/graphemic
(3) inflectional
(4) fingerspelling
(5) fingerspelling/spelling
(6) fingerspelling/phonologic
(7) spelling/phonologic
(8) spelling/inflectional
(9) phonologic
(10) semantic
(11) phonologic/semantic
(12) phonologic/semantic/spelling.

Examples of each are provided in the table below.

Print List (Examples):

Classification	Subject Response	Target Item
Spelling	Roomates	roommates
	Umberlla	umbrella
	Ptotoa	potato
	Evelator	elevator
	Girffe	giraffe
Spelling/Graphemic	Unbrella	umbrella
	Giratte	giraffe
Inflectional	Roommate	roommates
	Potatoes	potato

Spelling errors demonstrated some predictable patterns, including deletion ("roomates" for "roommates," "girffe" for "giraffe") and inversion ("umberlla" for "umbrella," "evelator" for "elevator"). However, some spelling mistakes ("ptotoa" for "potato") did not fit a predictable pattern. These will be discussed in an ensuing section.

Spelling/graphemic errors were coded when the subject confused two graphemically similar letters such as "n" and "m" ("unbrella" for "umbrella") or "t" for "f" ("giratte" for "giraffe").

Inflectional errors were coded when the subject made plural a singular stimulus item ("potatoes" for "potato") or made singular a plural stimulus item ("roommate" for "roommates"). Notice that in this kind of error, spelling integrity is preserved, though the target item is not replicated faithfully.

Fingerspelled List (Examples):

Classification	Subject Response	Target Item
Spelling	Light	lightning
	Lighting	lightning
	Lightening	lightning
	Twevle	twelve
Fingerspelling	Digisting	lightning
	Witch	watch
	F	fruit
	Flint	fruit
	RIT	fruit
Spelling/Fingerspelling	Light night	lightning
	Slove	twelve
	Wave	twelve
	Even	twelve
	Tewty	twelve
Fingerspelling/Phonologic	V	watch
Spelling/Phonologic	Vatch	watch
Spelling/Inflectional	Nucles	uncle

Spelling errors were pretty straightforward, consisting either of an inversion ("twevle" for "twelve"), deletion ("lighting" for "lightning"), omission ("light" for "lightning") or perception error ("lightening" for "lightning").

Errors were coded as fingerspelling errors if it appeared from the subject's response that he or she just plain missed the target item. In one case above ("digesting" for "lightning"), not only didn't the subject come close, but he or she didn't even manage to generate a real word. In other cases, the subject obviously caught a few letters and was able to map onto them another (albeit incorrect) word ("witch" for "watch," "flint" or "RIT" for "fruit"). In a final case, the subject only caught the first letter ("f") and was able to even guess at the word presented ("fruit").

Phonological errors are said to have occurred when the subject confused two similar appearing fingerspelled letters ("v" for "w").

An inflectional error was coded when, in addition to committing a reversal (spelling error), the subject made plural ("nucles") a singular stimulus ("uncle").

Sign List (Examples):

Classification	Subject Response	Target Item
Spelling	twety	twenty
	kicthen	kitchen
	Thurday	Thursday
	Apply	apple
	Buffyfying	butterly
Phonologic	Comfortable	gloves
	Money	Thursday
	Heat	grass
	Too much	adult
Phonologic/Semantic	Twelve (20)	twenty
Phonologic/Semantic/ Spelling	Sentative	heart

Spelling errors, once again, consisted of deletions ("twety" for "twenty," "Thurday" for "Thursday"), inversions ("kicthen" for "kitchen") and substitutions ("apply" for "apple"). The stimulus "butterfly" induced a class of intriguing error, one example of which is "buffyfying," which does not fit any of the categories just described.

Errors were coded as phonologic when it was clear that the subject mistook the stimulus sign for a formationally similar sign ("comfortable" for "gloves," "money" for "Thursday," "heat" for "grass" and "too much" for "adult"). Responding "twelve (20)" for "twenty" was classified both as phonologic and semantic, because "twelve" and "twenty" are orthographically similar (hence, a phonologic error), yet the subject demonstrated obvious semantic confusion (writing the numerical representation of "twenty," while writing the word "twelve"). Finally, writing "sentative" for "heart" was coded as a phonologic, semantic and spelling error, as "sensitive" (which the subject misspelled) is phonologically and semantically related to "heart."

Anomalous Errors

Though many of the errors detected conformed to predictable patterns (e.g., deletion, inversion, substitution), quite a few did not. In fact, a large percentage of subject responses did not even conform to the rules of written English. These particularly anomalous errors have been compiled in an effort to determine if one or more subjects account for the lion's share.

Print:

Subject	Error	Target
AB	Ptotoa	potato
	Eveltore	elevator
	Sevently	seventy
NJ	Giratte	giraffe

Fingerspelling:

Subject	Error	Target
AB	Slove	twelve
CP	Nicket	Ticket
	Vatch	watch
DH	Digisting	lightning
	Wich	watch
	Vo	vegetable
	Sasica	america
	Nicky	monkey
KM	p	lightning
KS	Vatch	watch
LC	S mica	america
NJ	Dight	lightning
	Tewty	twelve
	Vetch	ticket
	Sunny	Sunday

Sign:

Subject	Error	Target
AB	Beatifulily	butterfly
	Tewtly	twenty
DH	buffifying	butterfly
KM	Kihten	kitchen
LC	Beaufit	butterfly
	Twelve (20)	twenty
NJ	Atudy	adult

As the tables show, though anyone could make an anomalous error, three subjects (AB, DH and NJ) each made six such errors, far more than the rest of the subjects. While the anomalous errors made by DH and NJ are concentrated in the fingerspelling category, AB displays precisely the opposite error pattern. He makes only one anomalous fingerspelling error and instead has his anomalous errors almost equally split between the print and sign stimuli. There is, therefore, no discernible pattern for anomalous errors.

Interestingly, AB, DH and NJ have the most hearing (lowest PTAs) and lowest Michigan scores of all the subjects. In fact, their mean PTA is only 84 dB (SD = 10.15 dB), while the mean PTA of the remaining subjects is 108 dB (SD = 9.76 dB). Similarly, their mean Michigan score is only 41.67 (SD = 3.22), while the mean Michigan score of the remaining subjects is 50.89 (SD = 4.01). While it does not seem particularly surprising that those with the most anomalous errors would have the lowest Michigan scores, it does seem surprising that these same individuals would have the most hearing.

In other words, this select cohort of subjects demonstrates low language proficiency (by both Michigan score and error analysis), despite their relatively good hearing. This seems paradoxical, as one might expect those subjects with better hearing to have at least as good language as those with worse hearing. However, that these individuals have language issues despite their better hearing suggests that there is something else at play. Is it possible that these subjects are genuinely learning disabled? If so, spelling performance might yet prove a plausible way to differentiate deaf LD individuals from "garden variety" poor deaf readers!

Conclusion

This study should be repeated on a larger scale with a larger subject pool that includes equal numbers of "good" and "poor" deaf readers. Furthermore, the four items deleted for reasons of ambiguity ("world," "morning," "knife" and "rooster") ought to be eliminated permanently from the stimuli materials.

Appendix A (Stimulus Lists)

List Item	Fingerspelling	Sign	Print
1	Lightning	Mother	Roommates
2	Twelve	***Knife****	Smoke
3	Ticket	College	Circus
4	Watch	Person	Umbrella
5	Fruit	Twenty	Turkey
6	Sunday	***Rooster****	Potato
7	Vegetable	Gloves	Horse
8	America	Kitchen	Elevator
9	Monkey	Color	Hammer
10	***World****	Heart	House
11	Grapes	Thursday	Garage
12	Glass	Baseball	Giraffe
13	Pocket	Grass	Seventy
14	Uncle	Office	Fifteen
15	***Morning****	Dance	Bacon
16	Bread	Apple	Cloud
17	Coffee	Butterfly	Dinner
18	Dream	Adult	Eleven
Mean Character Number	**6.06 (SD = 1.22)** **revised = 6.07*	**6.17 (SD = 1.21)** **revised = 6.19*	**6.28 (SD = 1.15)**
Mean Word Recognition Frequency	**77.49% (SD = 6.56)** **revised = 78.08%*	**77.94% (SD = 7.04)** **revised = 75.21%*	**75.05% (SD = 9.47)**

Figure 1. List Characteristics (Items, Mean Character Number, Mean Word Recognition Frequency)

****Fingerspelled items 10 & 15 and signed items 2 & 6 were eliminated for data analysis, as they were determined to be ambiguous or unclear. Revised means have been calculated without these four items.***

	Character Number = 5	6	7	8	9
Fingerspelling	7	7	2	0	2
Sign	7	5	3	2	1
Print	5	7	3	2	1

Figure 2. Word Frequency Distribution by Character Number and List

Appendix B (Consent Form)

Agreement to Participate in Research

For

Susan R. Post,
Susan Fischer, Ila Parasnis & Vincent Samar

CONSENT FORM for Non-Medical Human Subjects

DESCRIPTION: In this study you will complete three tests. In the spelling test, you will write down the fingerspelled, signed and printed words you see. In the Digit Span test, you will recall and write down numbers between two and seven digits. Finally, in the Symbol Digit Modalities Test (SDMT), you will "translate" a sequence of nonsense symbols using the key provided.

RISKS AND BENEFITS: There are no known risks associated with your participation in this project.

TIME INVOLVEMENT & COMPENSATION: It will take about an hour of your time to participate in this study. You will receive a certificate for Ben & Jerry's ice cream for participating in this study.

SUBJECT'S RIGHTS: Your participation is voluntary and you have the right to withdraw your consent or discontinue participation at any time without penalty. You have the right to refuse to answer particular questions. All information will be kept strictly confidential and your name will not appear in any presentations and/or publications that may result from this research.

I have read the information above and I voluntarily agree to participate in this study. I give researchers permission to use information acquired through today's testing, as well as through student databases (admission information, audiological records, etc.) for this particular study.

SIGNATURE ______________________________ DATE ____________

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